Urban Computing

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Third Session: Urban Computing - Data visualization

Agenda for this session

- Part 1: Data visualization fundamentals
  - Perception
  - Data types
  - Visual mapping
- Part 2: Visualizing spatio-temporal data
  - Visualizing space
  - Visualizing time

Part 1: Data visualization fundamentals

What is data visualization?

Data visualization

"Data graphics visually displaying measured quantities by means of the combined use of points, lines, a coordinate system, numbers, symbols, words, shading, and color"
Edward R. Tufte

What is visualization

- We define visualization as the communication of information using graphical representations.
- A high quality visualization is:[1]
  - Truthful
  - Functional
  - Visually pleasing
  - Insightful
  - Enlightening

[1] Alberto Cairo. *The truthful art: Data, charts, and maps for communication*. New Riders, 2016.

Who do you visualize for?

Depends on the purpose:

- Exploratory data visualization
- Explanatory data visualization

Perception in Visualization

Perception is the process of recognizing, organizing, and interpreting sensory information.

- Attentive (controlled)
- Pre-attentive (uncontrolled)

Example: in the picture to be shown, count the number of threes

How many numbers of 3 you see in this picture?

183748063803642941489443270652256588753477874541488903270754548017280875387124743224567237523102355321789986322457900888231806234358759923682456423298934235089121274565345899645804733258689745241989412312456007765097532234687320242389 1

How many numbers of 3 you see in this picture?

183748063803642941489443270652256588753477874541488903270754548017280875387124743224567237523102355321789986322457900888231806234358759923682456423298934235089121274565345899645804733258689745241989412312456007765097532234687320242389

How many numbers of 3 you see in this picture?

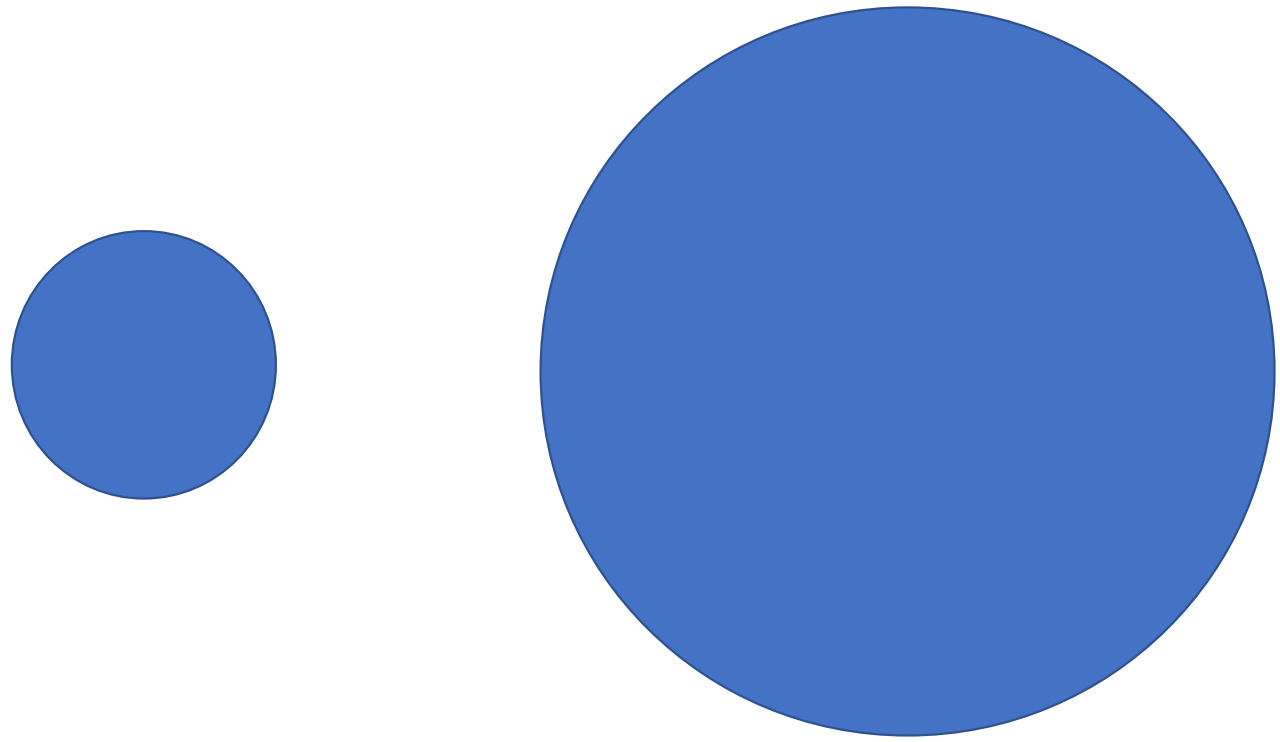
18374806380364294148944327065225658875347787454
14889032707545480172808753871247432245672375231
02355321789986322457900888231806234358759923682
45642329893423508912127456534589964580473325868
97452419894123124560077650975322346873202423891

Answer: 28

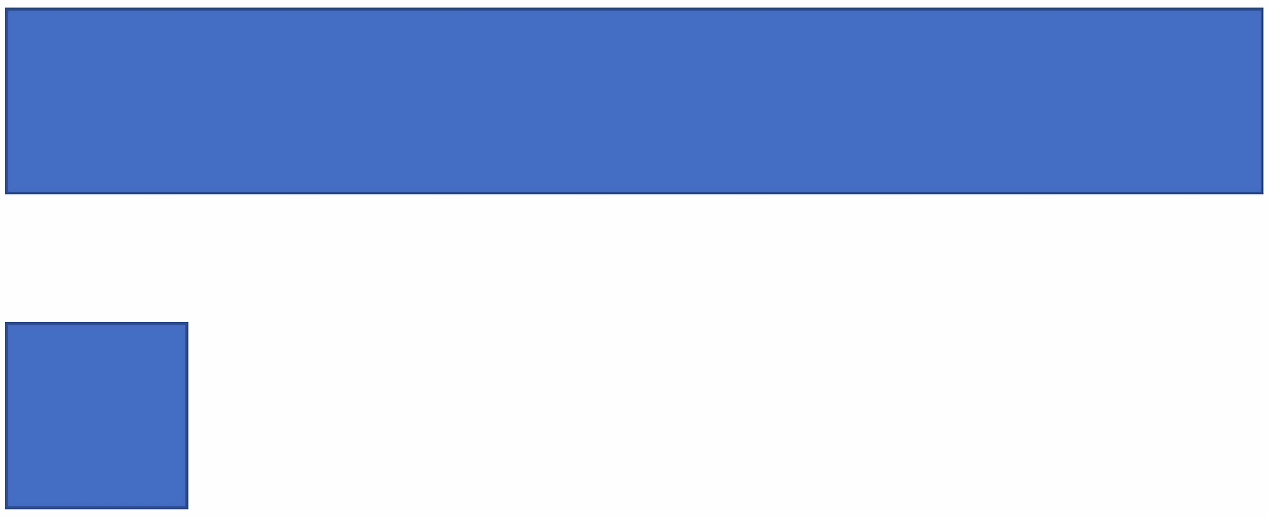
Sometimes perception issues are more complicated than that...

Example two: Try to guess the ratio between the bigger shape and the smaller shape ...

What is the ratio between the bigger and the smaller circle?



What is the ratio between the bigger and the smaller rectangle?



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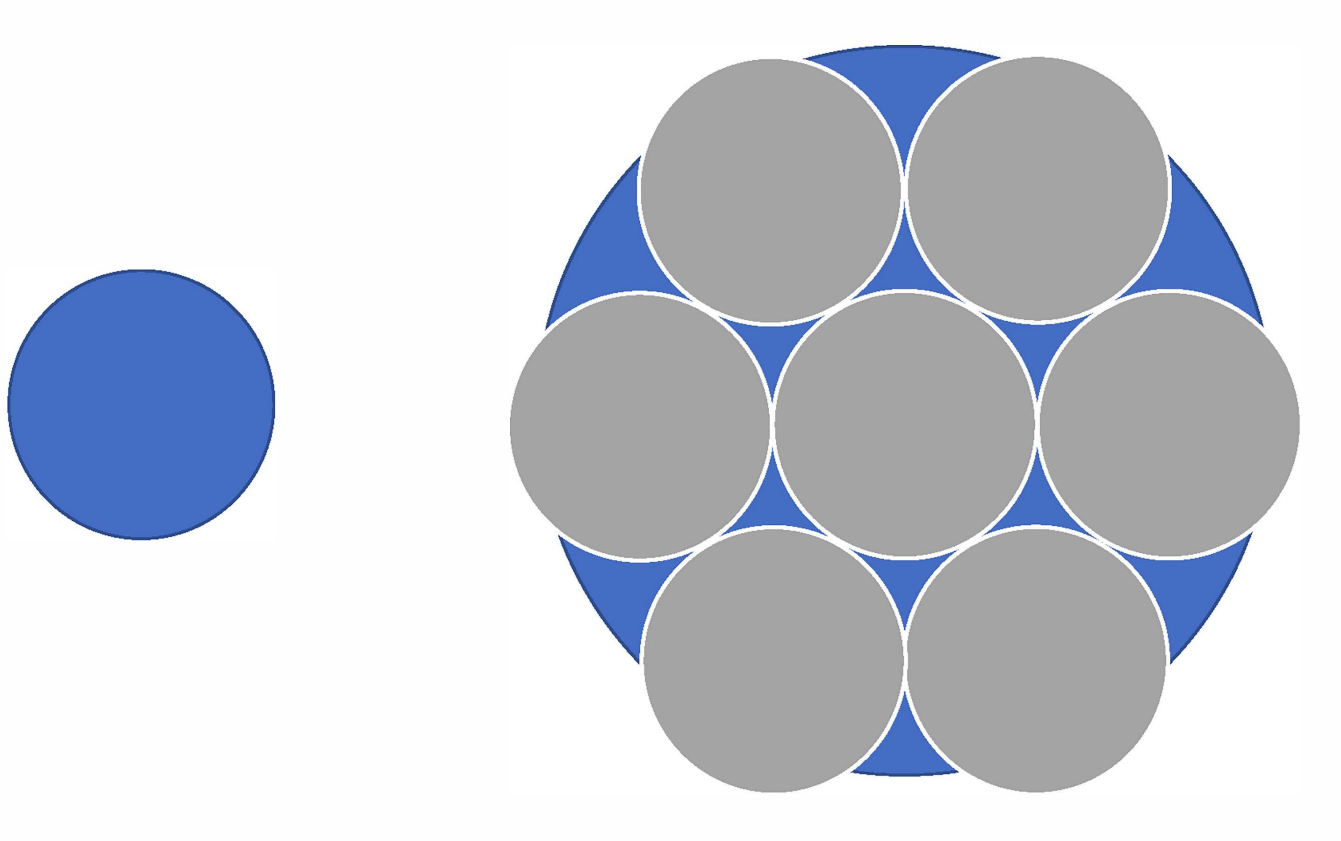


What is the ratio between the bigger and the smaller rectangle?

Visualization basics: Data

- Visualizing is about mapping data to the right visual attribute
- Data
  - Nominal
  - Ordinal
  - Quantitative
- What matters a lot is the operations we can apply on data. A good visual attribute helps us keep those operations.

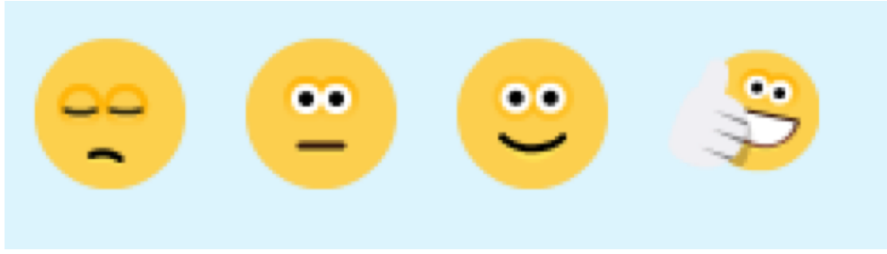
Nominal

- Categories
- Names

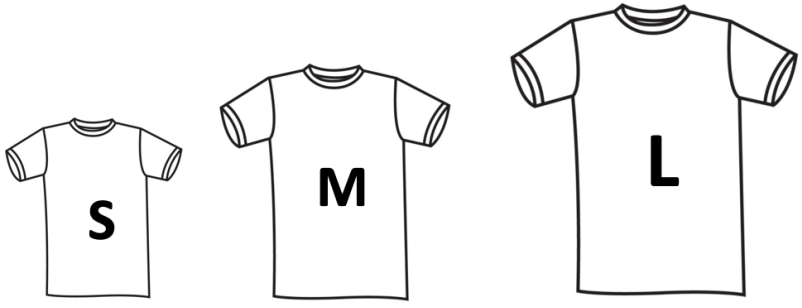
Mary
John
Jack

Ordinal

Categorical data type where the variables have natural, ordered categories and the distances between the categories is not known



Disagree Neutral Agree Strongly agree



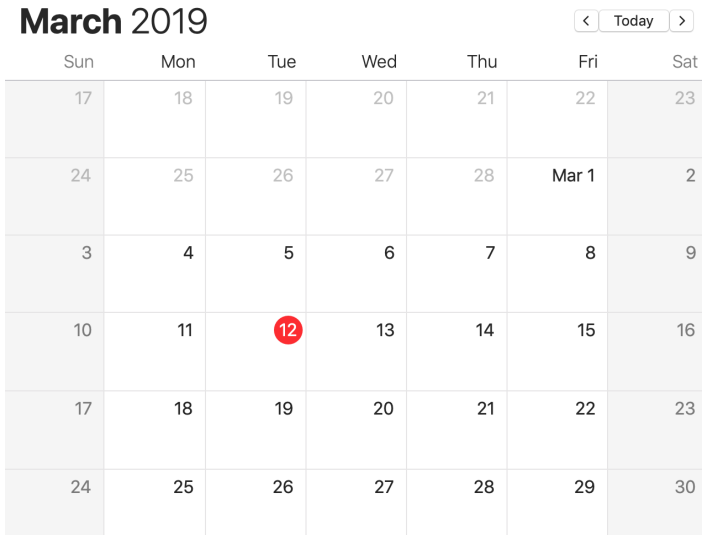
Freshman
Sophomore
Junior
Senior

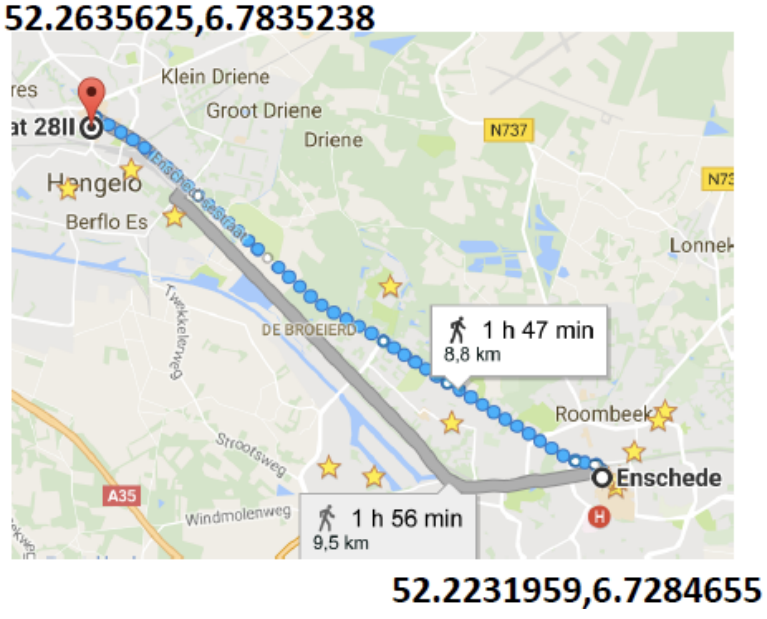
Quantitative

- Discrete $\{i \in \mathbb{N}\}$
- Continuous $\{i \in \mathbb{R}\}$

Quantitative continued

- Some distance metric can be defined
- You cannot divide them, ratios don't mean anything





Visual mapping

- How to map data to visual attributes such that operations are perceived visually ...

Visual mapping

- How to map data to visual attributes such that operations are perceived visually ...
- What visual attributes you know?

Visual encoding- Jacque Bertin

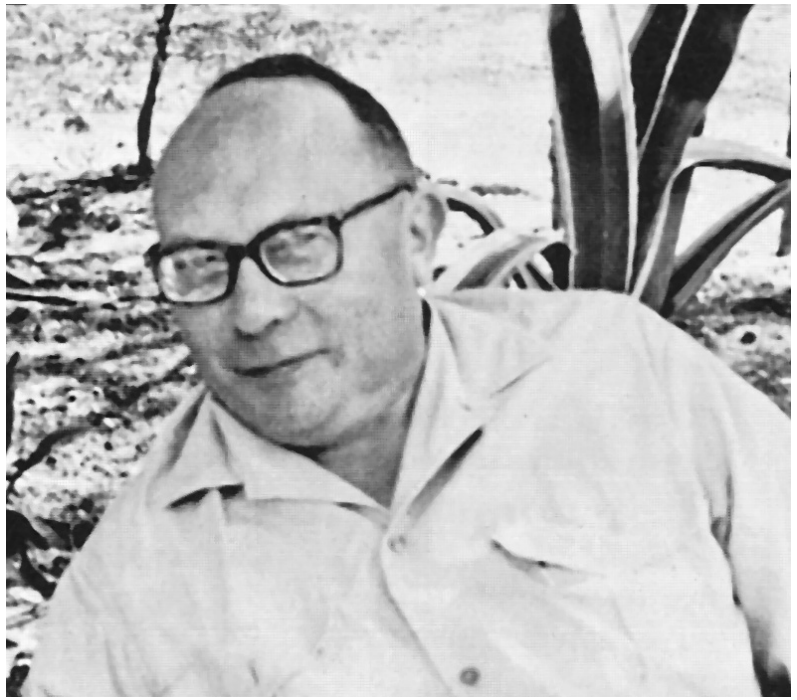


Figure: Jacque Bertin 1918-2010

[2]

[2] https://en.wikipedia.org/wiki/Jacques-Bertin

Jacque Bertin

- Bertin presents the fundamentals of information encoding via graphic representations as a semiology (sign systems)
- **Visual encoding** is the process of mapping data into visual structures
- Bertin's graphical vocabulary:

Marks	Points, lines, areas
Positional	Two planar dimensions
Retinal	Size, value, texture, color, orientation, shape

Jock Mackinlay

Quantitative data

Position

Length

Angle

Slope

Area

Volume

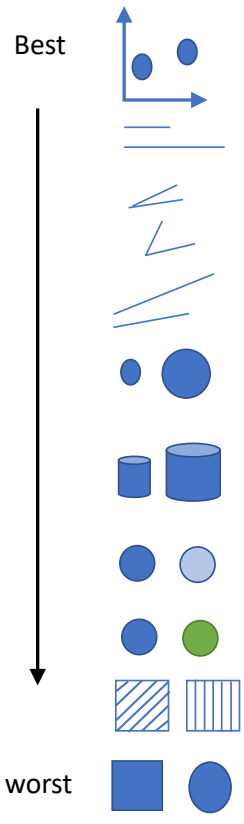
Color saturation

Color hue

Texture

Shape

Jock MacKinlay



Quantitative data

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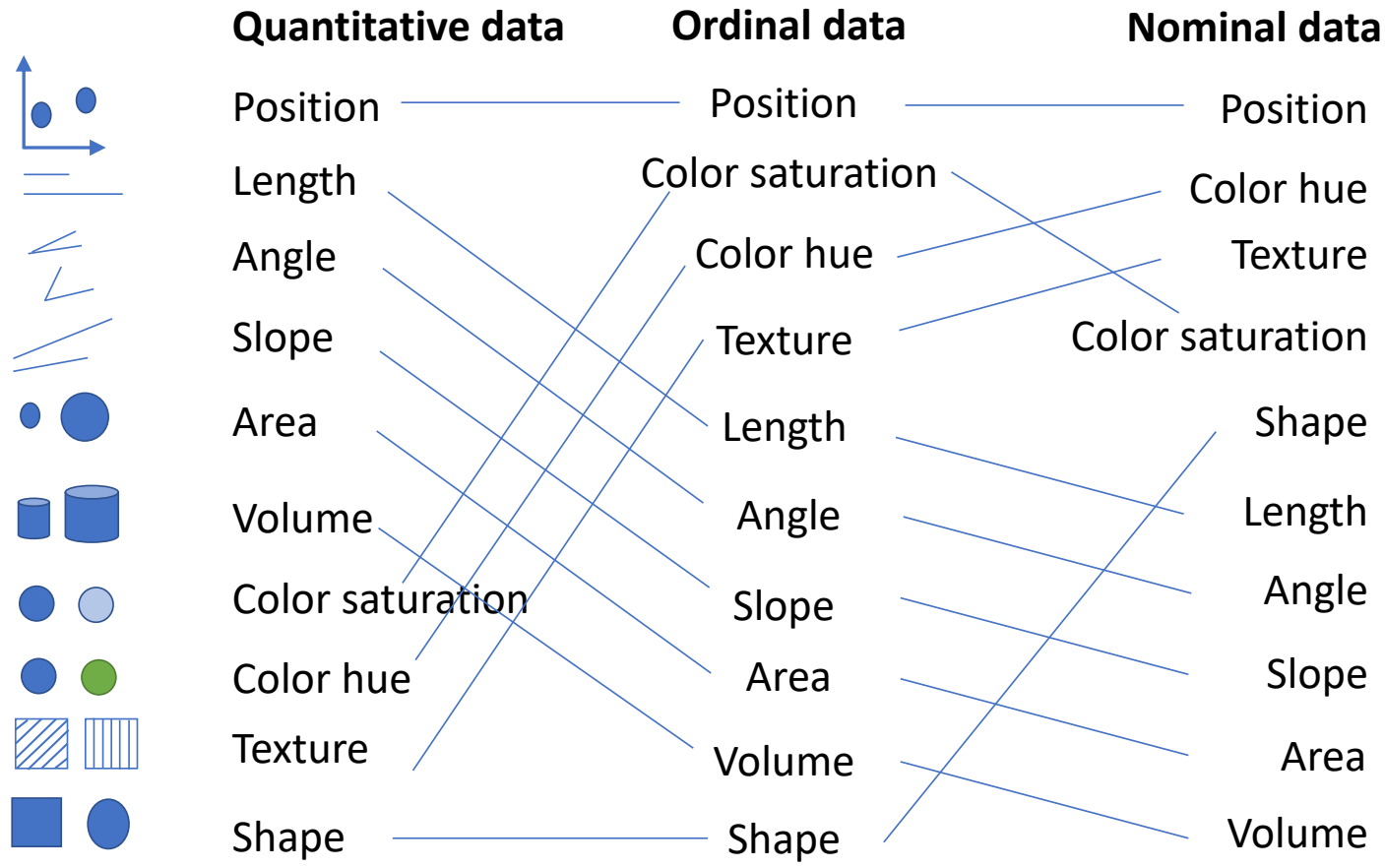
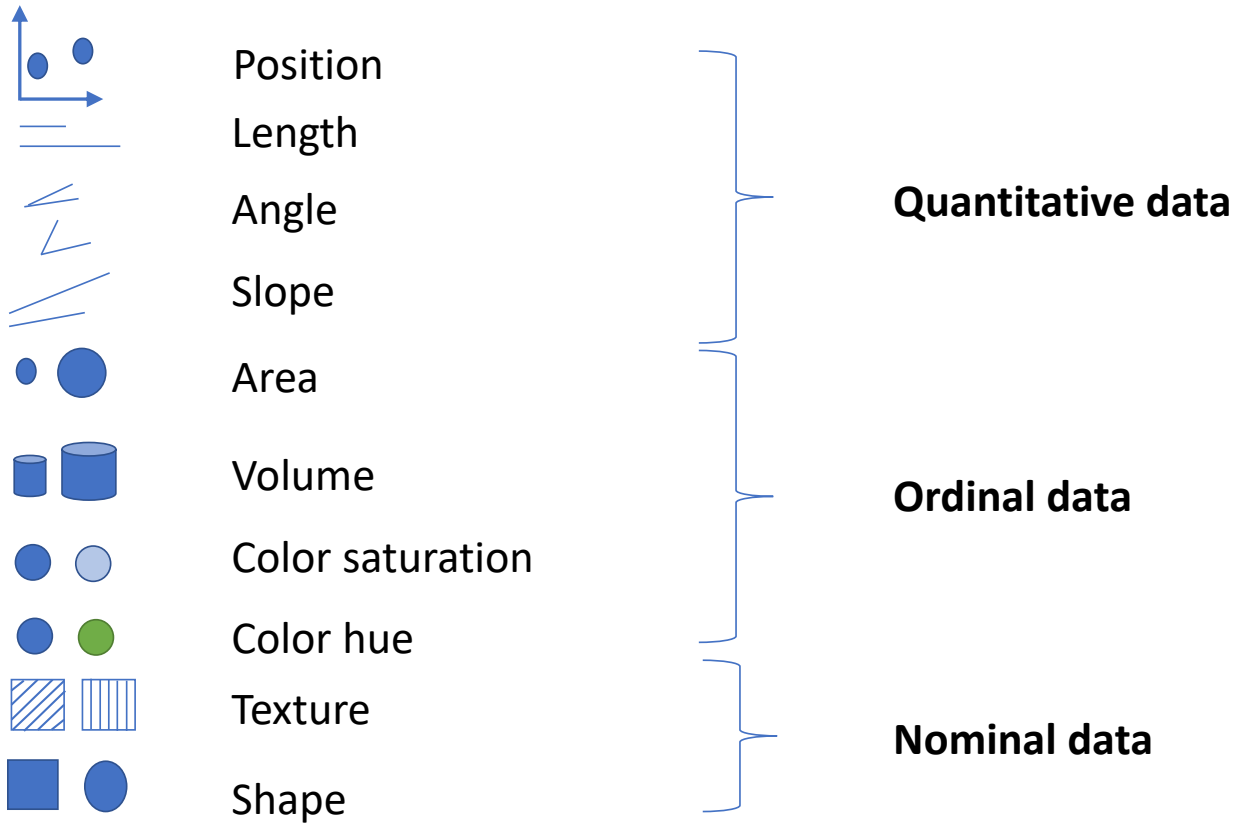
Jock MacKinlay



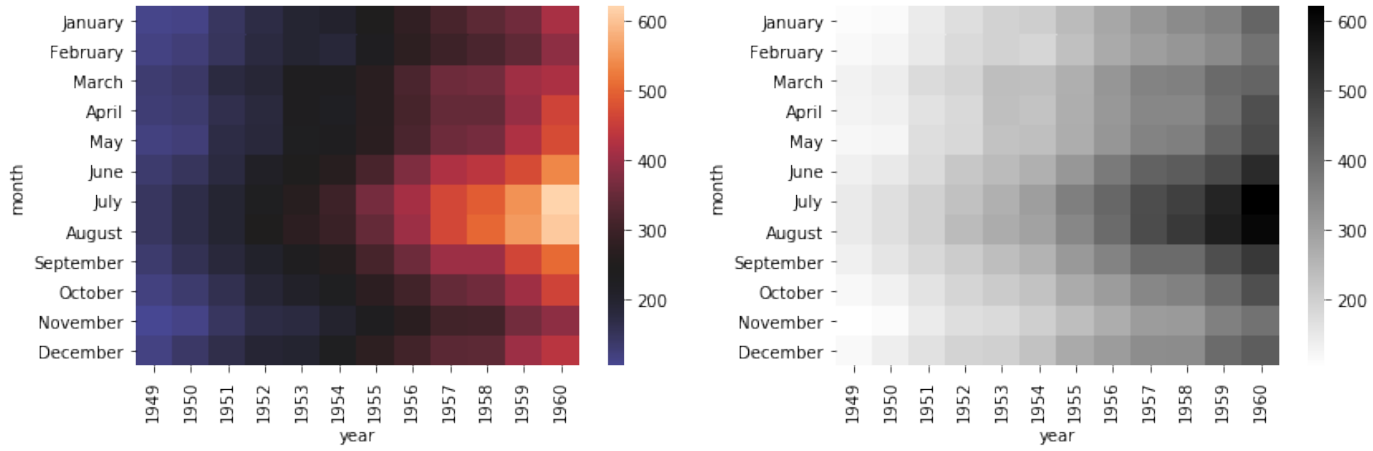
Visual mapping



Not only useful for visual designers but also for designing automatic visualization algorithms

Example

Which one is more efficient?



Example

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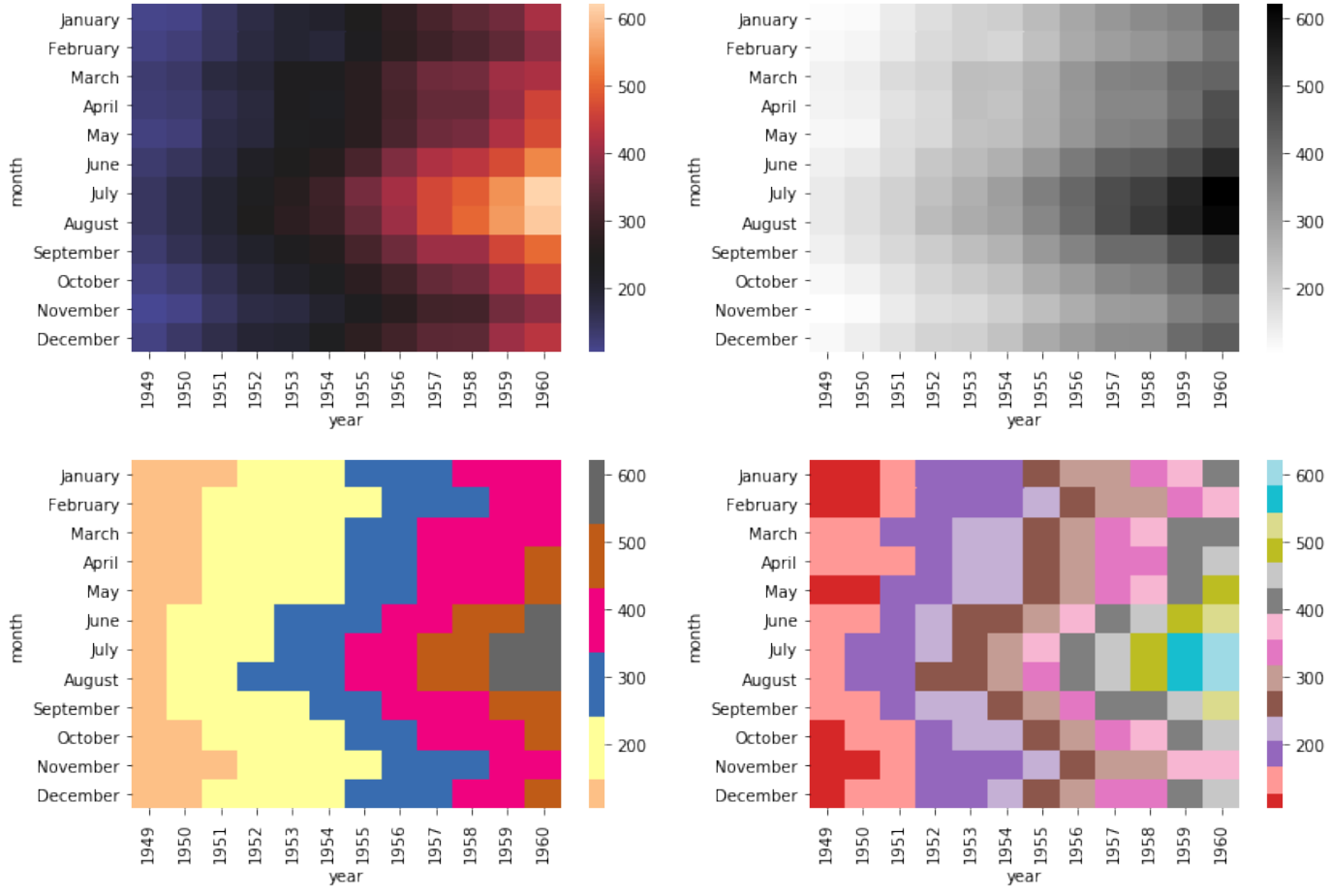

Part 2: Visualizing spatio-temporal data

Visualizing spatio-temporal data

- Spatial data
- Temporal data

A bit of history

3

- Original map made by John Snow in 1854.
- Map of the deaths from cholera in London in 1663.
- Each bar represents one deceased person

[3] image source: https://nl.wikipedia.org/wiki/John_Snow

A bit of history

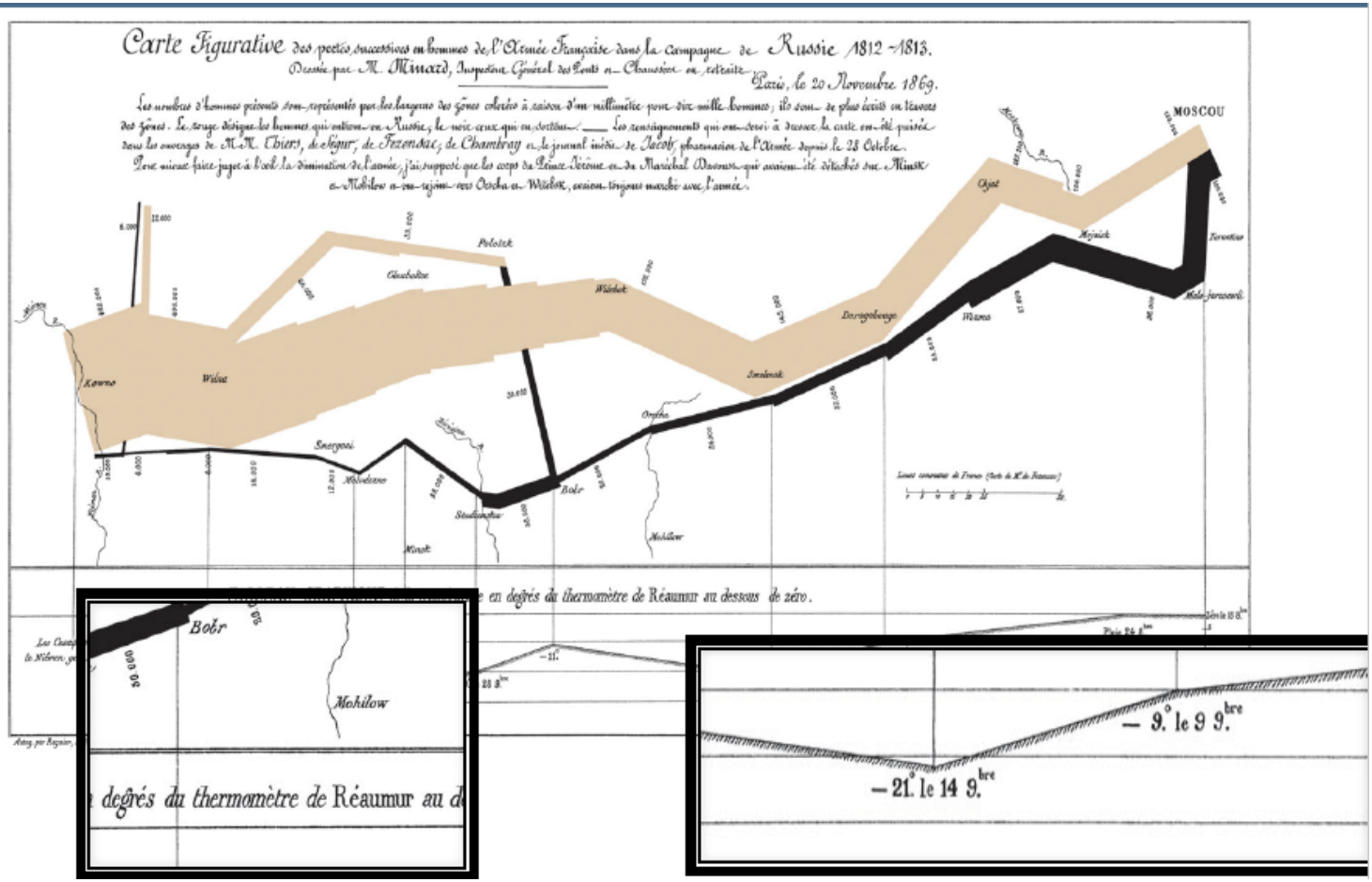

Figure: The map of Napoleon's Russian campaign

[4] image source: https://en.wikipedia.org/wiki/Charles_Joseph_Minard

Visualization technique for geo-spatial data

- What is so difficult about making maps?

The orange effect

[5]

[5] Image source: www.profdrikageografia.blogspot.com/2010_12_01_archive.html

Projections

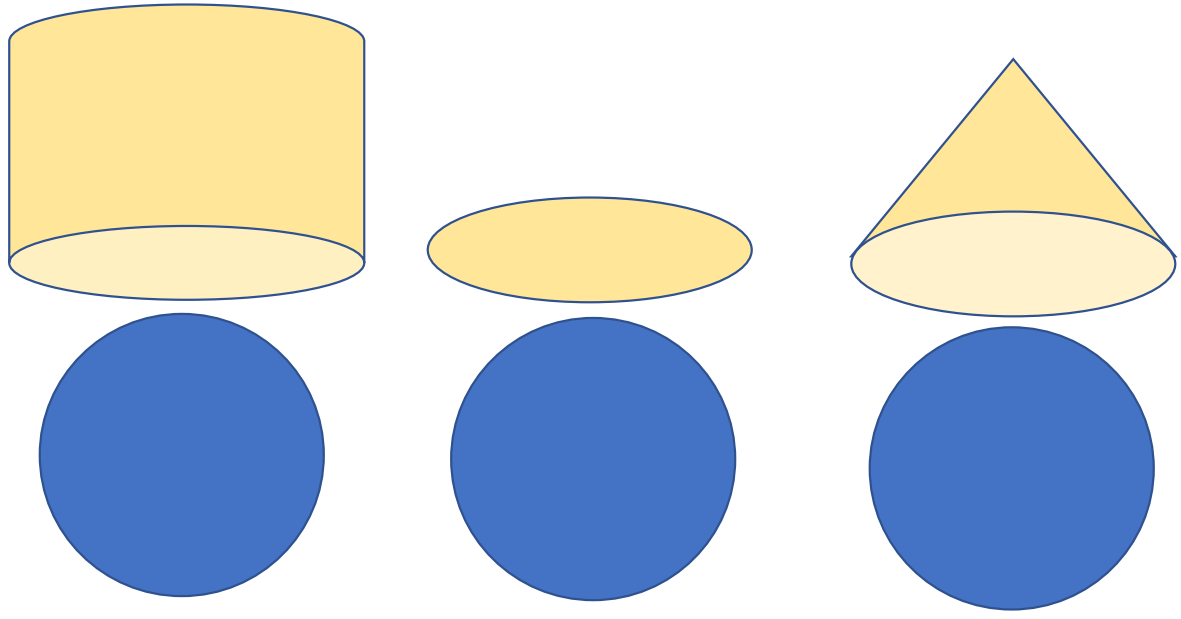

Figure: Methods of projection: Cylindrical, Circular, Cone

Map projection techniques

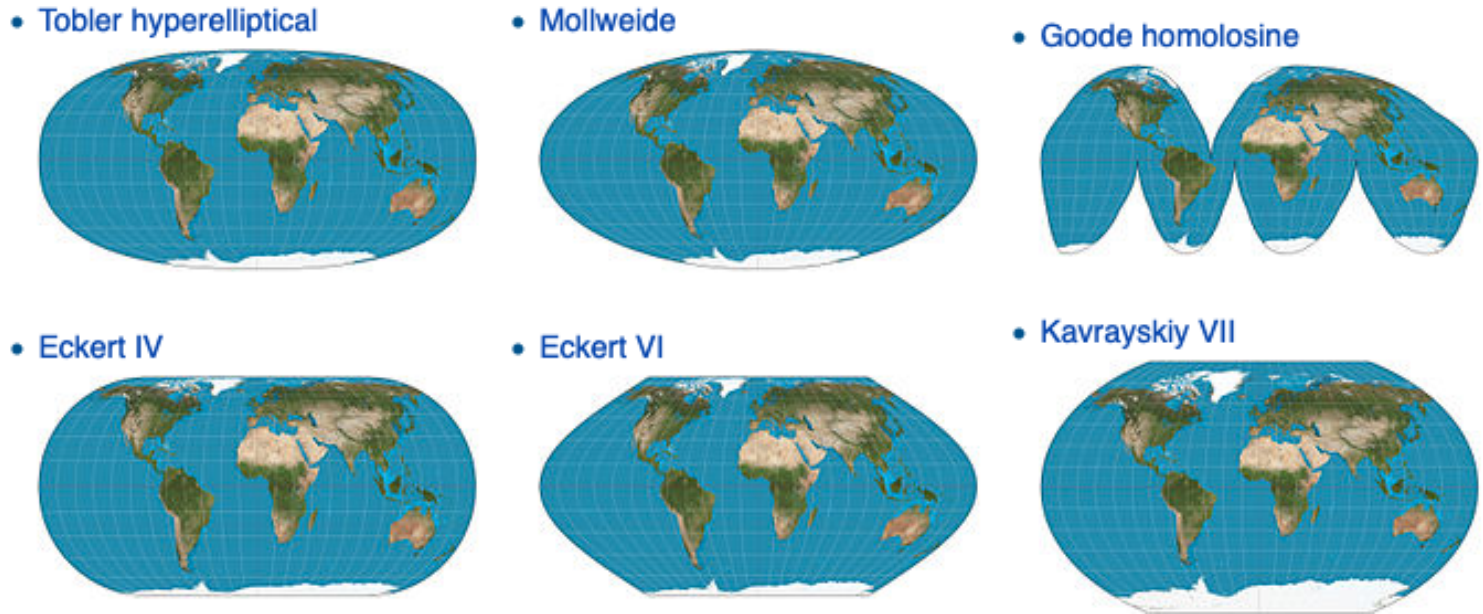

Figure: A number of pseudo-cylindrical map projection techniques

6 7

[6] image source: https://en.wikipedia.org/wiki/Map_projection

[7] image credit Copyright ©[2011] [Daniel R. Strebe].

Attributes we would like to save in a projection

- Shape
- Area
- Angle
- Distance
- Direction

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- Angle
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A projection can preserve one or two of these properties $\rightarrow$ At least three attributes will be sacrificed.

Merkator projection

Mercator projection is the de facto standard for web mapping applications (Open street maps, Google maps, etc.)

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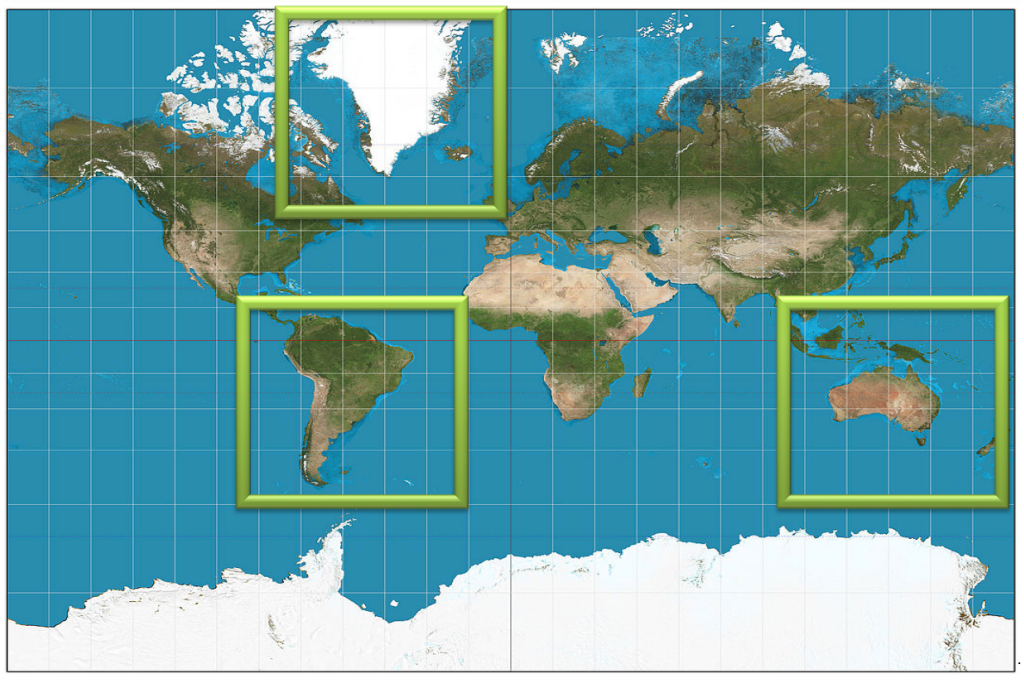
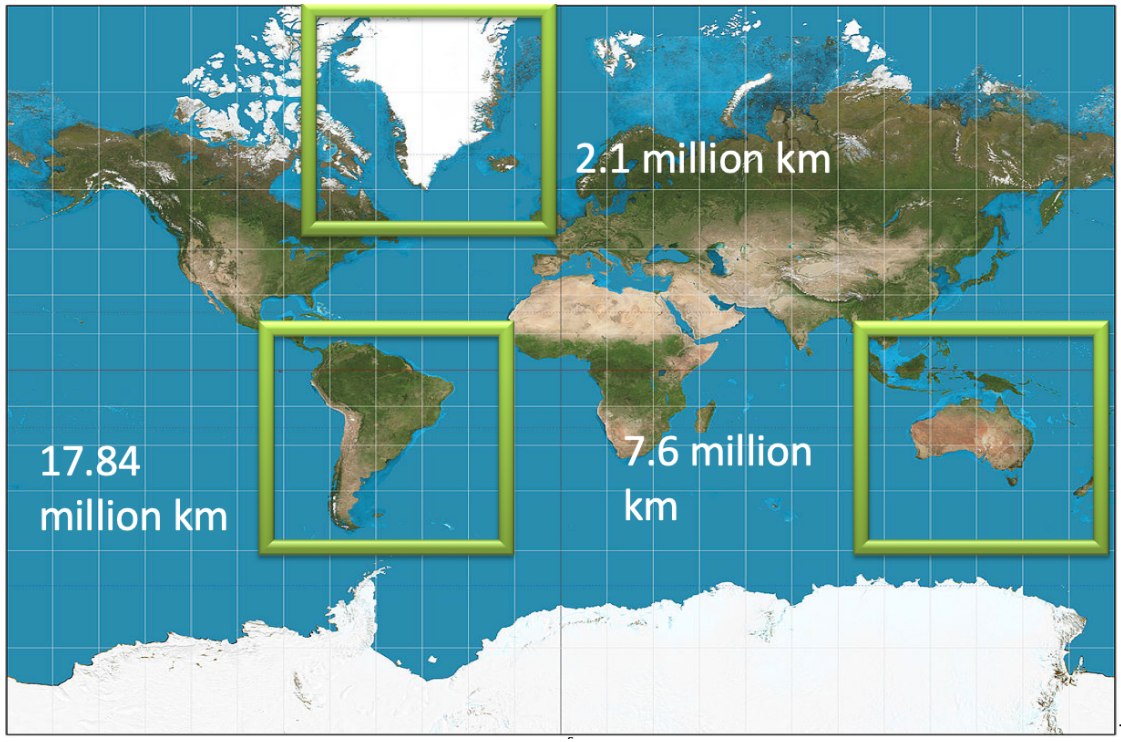
Everything near the equator is in the right size, the rest are not!

Merkator projection



Merkator projection



Which projection should you use?[8]

- Continental areas: Asia and North America
  - Albers equal-area
  - Lambert azimuthal
- Countries in mid-latitude
  - Albers equal-area
  - Lambert azimuthal
  - Cylindrical equal-area
- **Continental areas: Europe and Australia**
  - Albers equal-area
  - Lambert azimuthal
- Polar regions
  - Lambert azimuthal
- Continental areas: Africa and South America
  - Lambert azimuthal
  - Mollweide
  - Sinosoidal
- **Small countries**
  - Lambert equal area
  - Cylindrical equal area

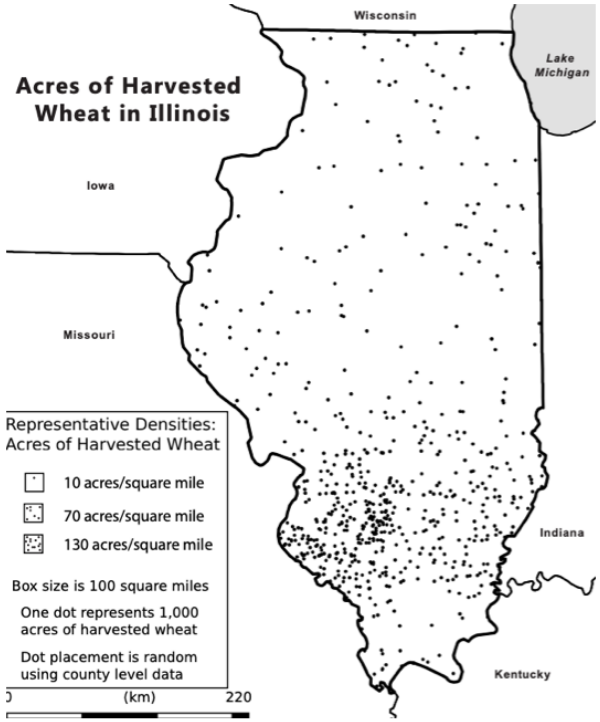
[8] Alberto Cairo. *The truthful art: Data, charts, and maps for communication*. New Riders, 2016.

Example

Given a dataset with phone call instances, how will you show it on a map?

Longitude	**Latitude**
52.168141	4.470163
52.168341	4.470133
52.168335	4.470236
52.168828	4.471694

Example



Problem with dotmaps: if we draw a dot for every instance there will a large degree of overlap. [9] [10]

[9] https://en.wikipedia.org/wiki/Dot_distribution_map

[10] image credit Copyright ©[2014] [Ziegenf2].

Visualizing area data

Thematic maps:

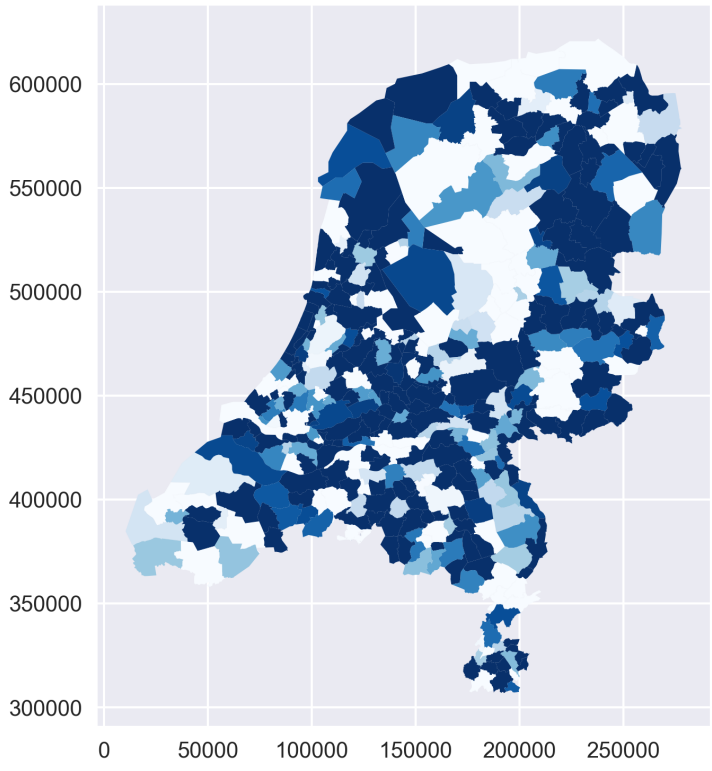


Figure: A choropleth map, colors mapped to numbers

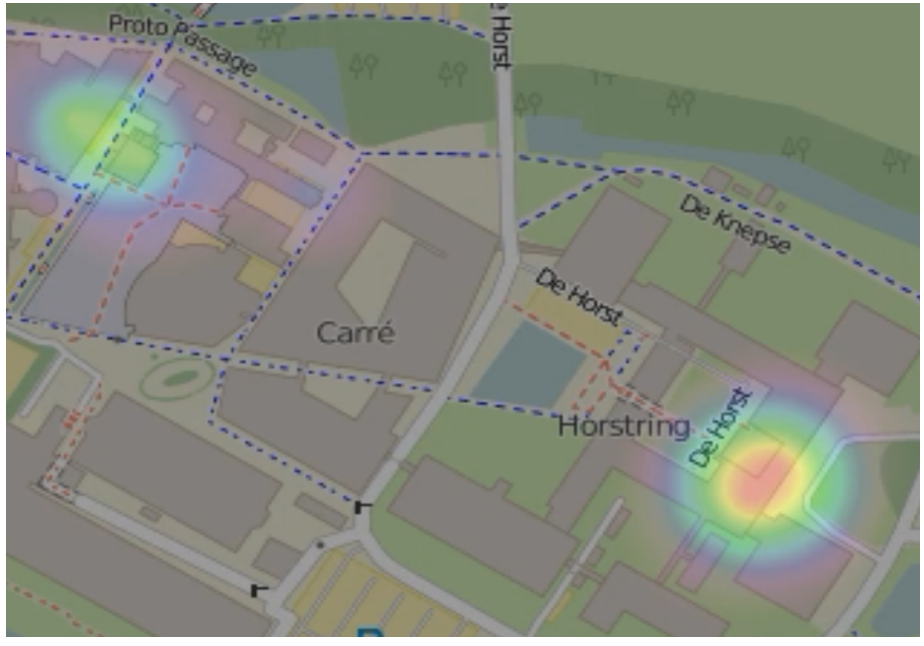
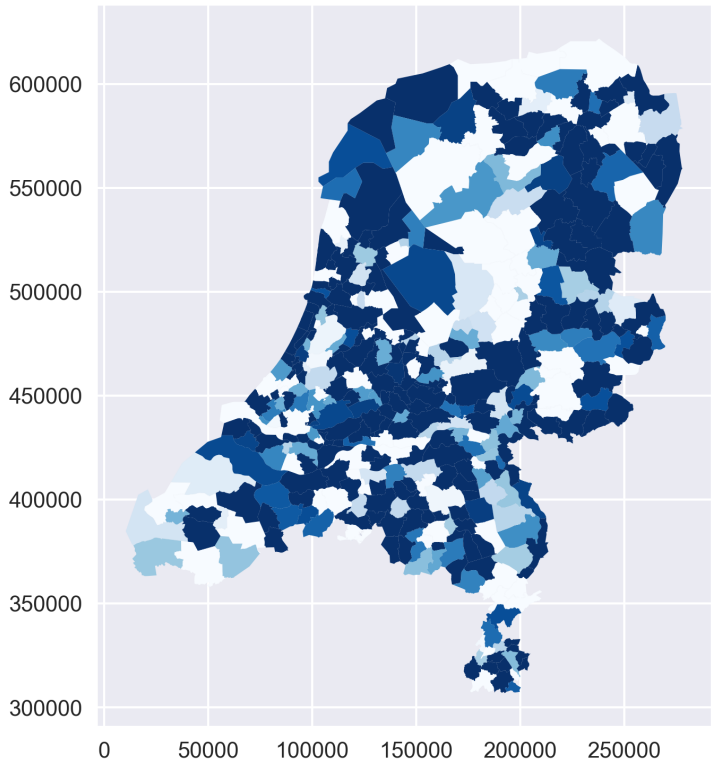


Figure: An isarithmic map showing the density of a variable

Choropleth maps (Area data)

A map which uses differences in shading, coloring, or the placing of symbols within predefined areas to indicate the average values of a particular quantity in those area

Choropleth maps (problems)



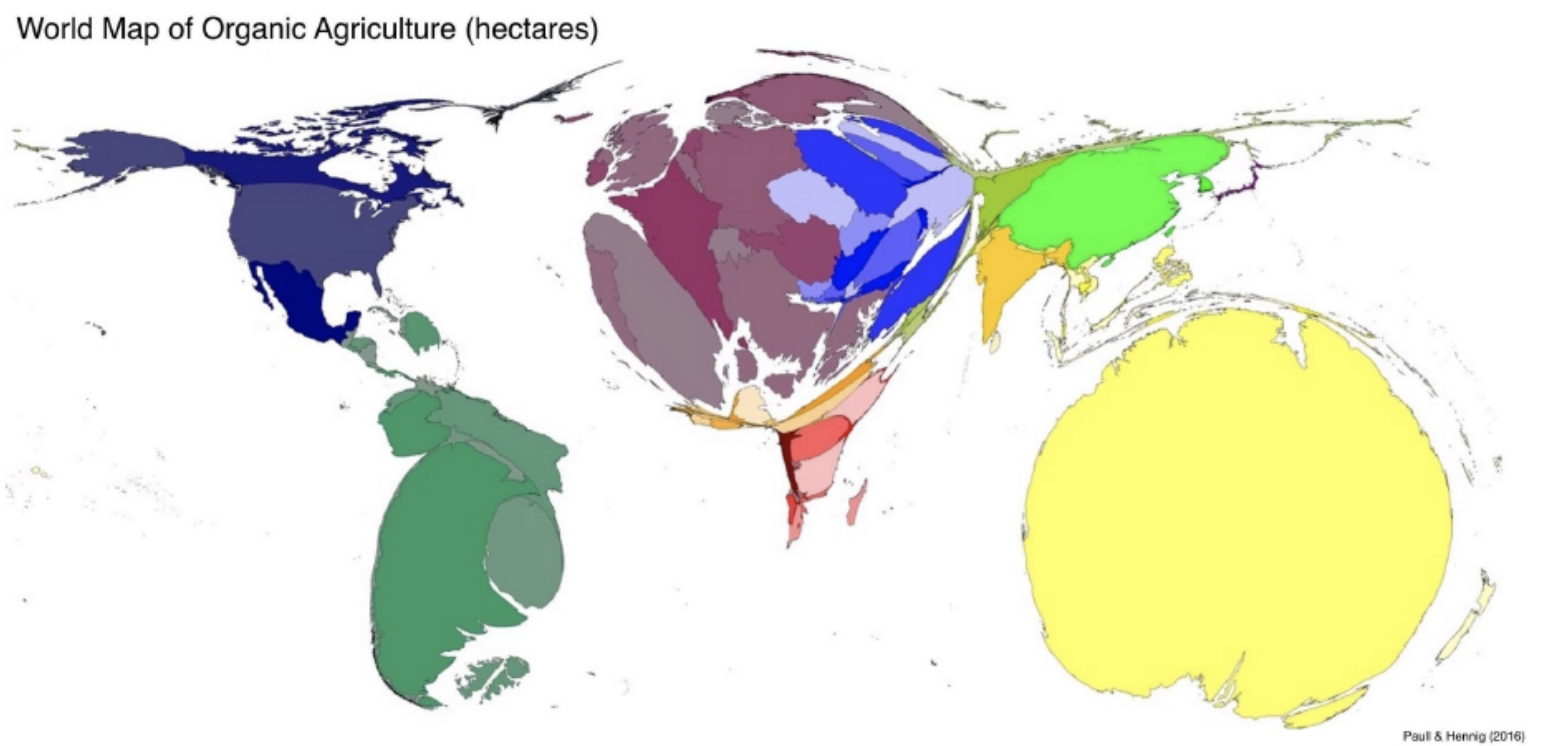
Problems with Choropleth maps

- Most interesting values are often concentrated in densely populated areas with small polygons. Less interesting values are spread over sparsely populated areas with large polygons.
- **Choropleth maps tend to highlight patterns in large areas, which may be of lower importance.**

Cartograms

Cartograms are generalizations of ordinary thematic maps that avoid the problems of choropleth maps by **distorting the geography** according to the displayed statistical value.

World map of organic agriculture (hectares)

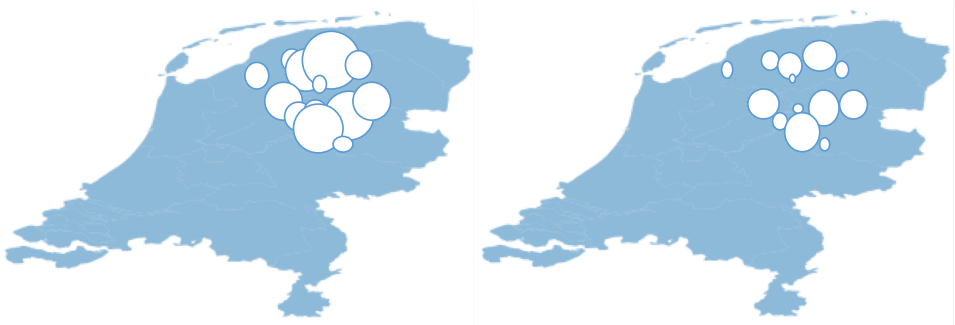


11 12

[11] image source: https://en.wikipedia.org/wiki/Cartogram

[12] image credit Copyright ©[2016] [John Paull and Benjamin Hennig]

Comparing areas of different size requires normalization



- Same data will yield different visualization when normalized considering population densities
- Normalize data before visualizing!

Points to consider in maps (perception problems)

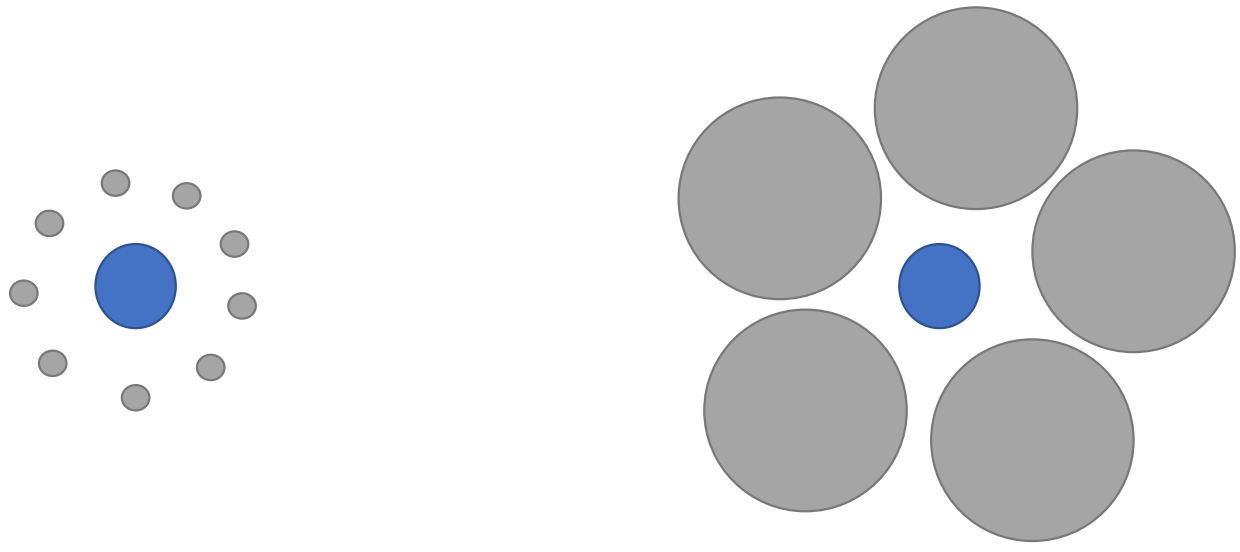


Figure: Ebbinghaus illusion

Points to consider in maps

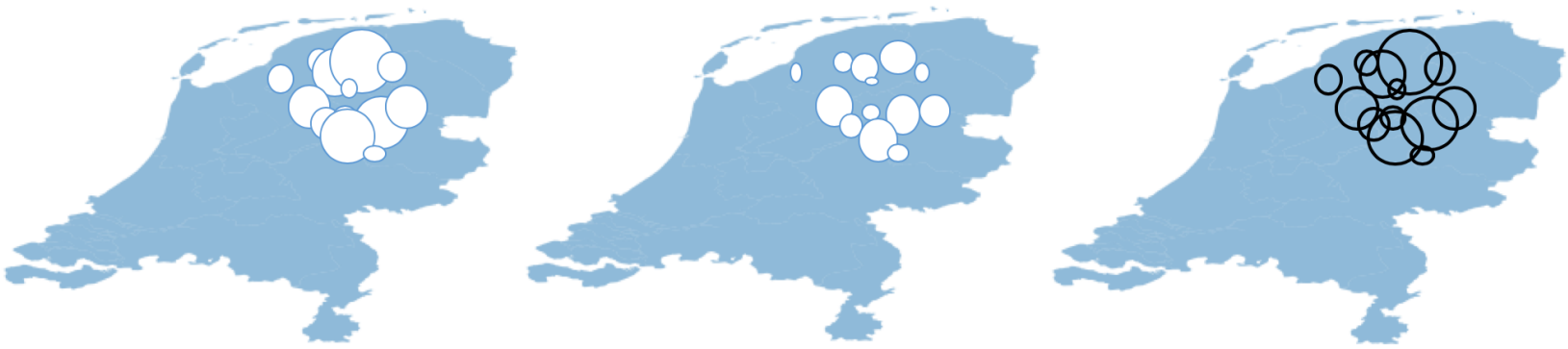
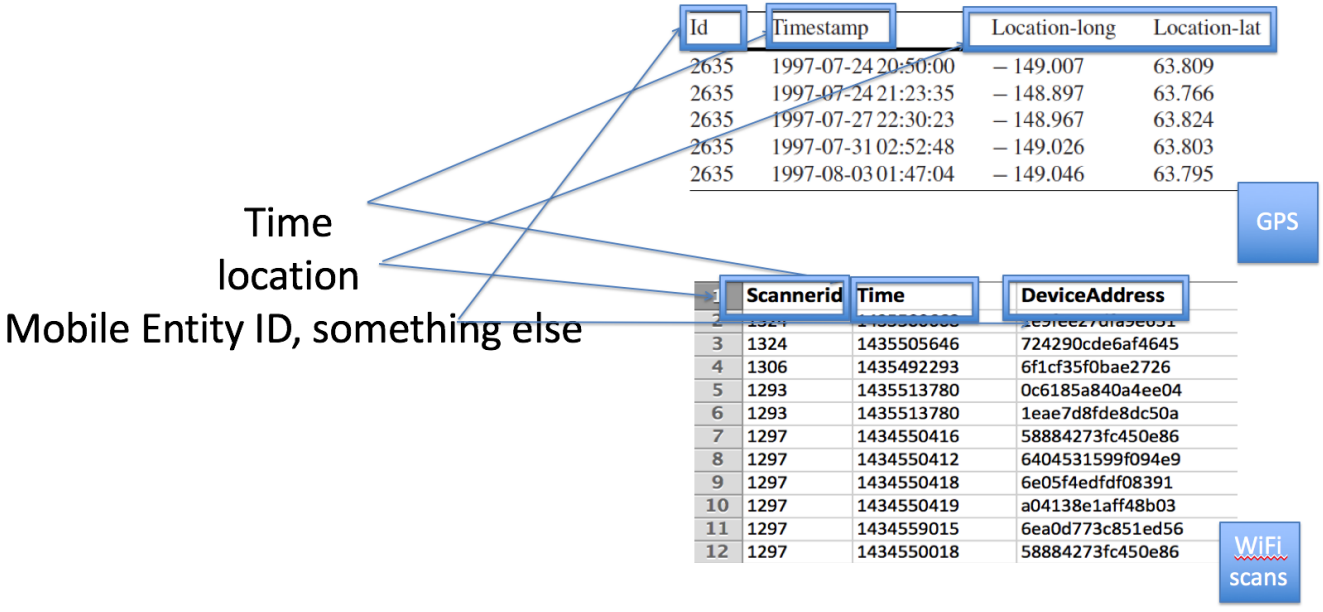


Figure: Overlapping points on maps, try to prevent the left image using normalization or transparent circles

Spatio-temporal data



Visualizing spatio-temporal data

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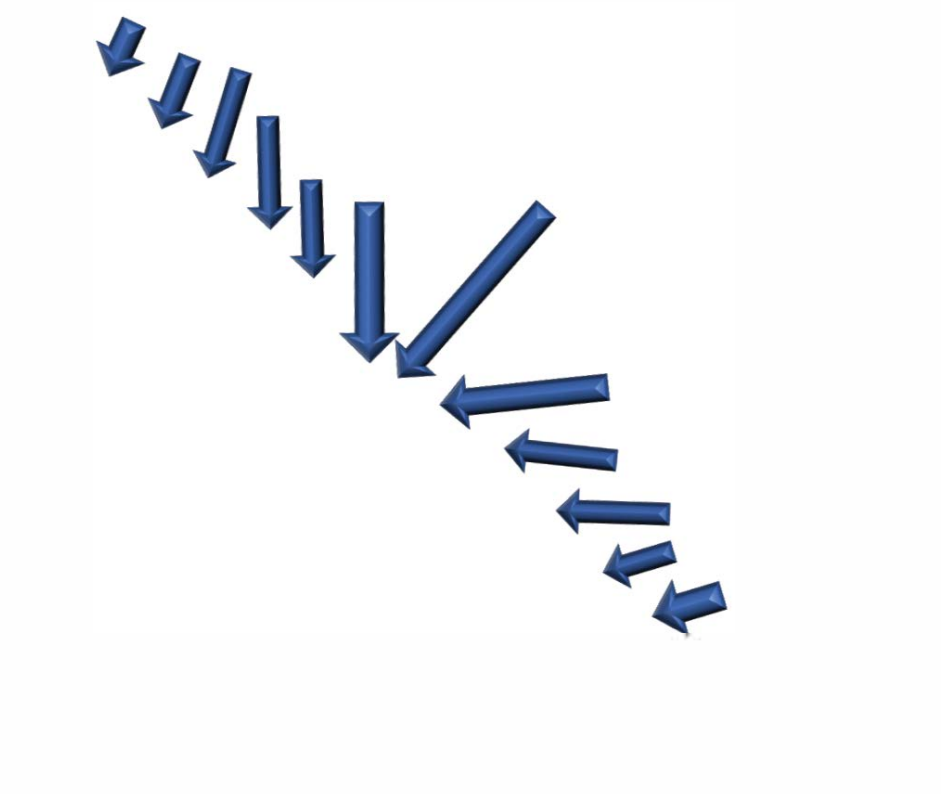
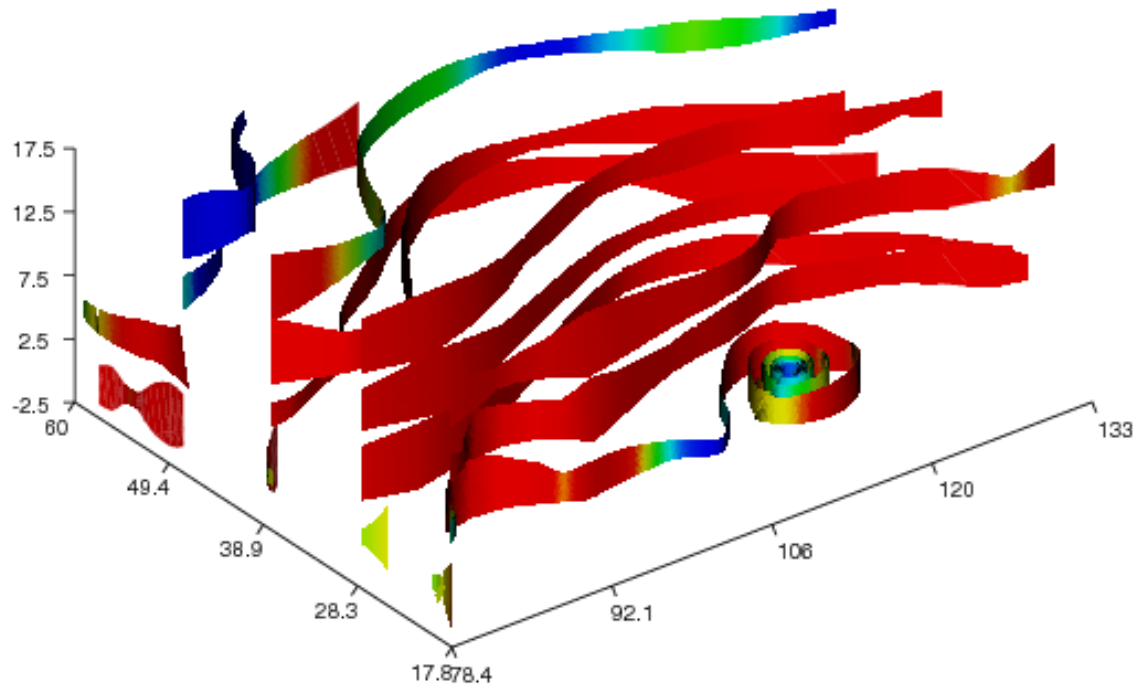
- It is important to use techniques to allow focus on a specific phenomena in visualization
- Example of technique for visualizing temporal data:
  - Glyphs
  - Ribbons
  - Streaklines

Glyphs



Glyphs can have a direction and strength.

Ribbons

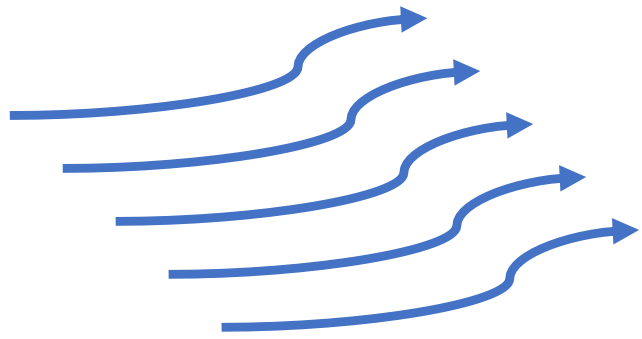


Flow data visualized using ribbons, vorticity can be mapped to twist. [13]

[13] image source:http://hplgit.github.io/scitools/doc/easyviz/easyviz.html

See here

Streaklines

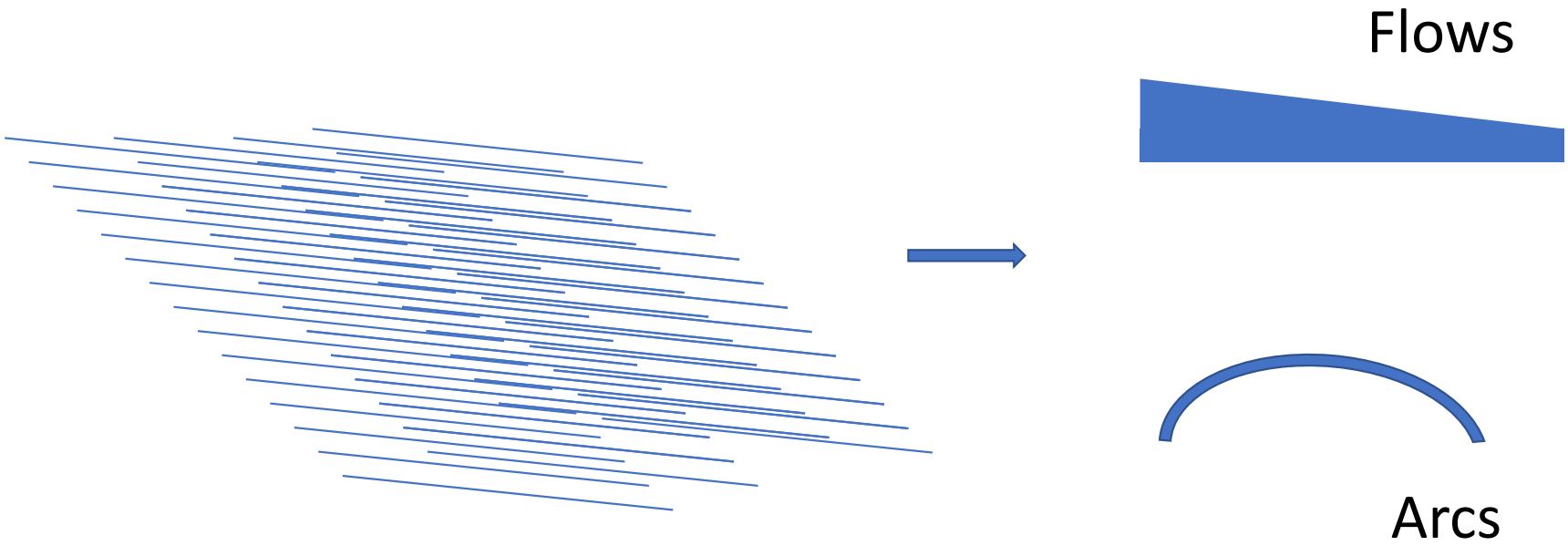


Points from a number of timestamps can be joined to form streaklines.

Visualizing flows on maps

How to deal with so many lines?

- Flow maps
- Arc maps



Lessons learned

- Fundamental of visual mapping
  - Perception: attentive, and pre-attentive
  - In organizing the visualization we need to make sure that important information is pre-attentively perceived
  - Data types (nominal, ordinal, and quantitative) and operations applicable on them
  - Visual attributes (shape, color, position, etc.)
  - Visual mapping should be performed by choosing the the visual attribute that can preserve the operations on data types

Lessons learned (continued)

- Visualization of spatio-temporal data
- Projection techniques and important spatial attributes that need to be preserved (shape, area, angle, direction, distance)
- Challenges of presenting area data over area:
  - Dot plots, thematic maps, cartogram
- Visualizing the time by focusing on temporal aspects (glyphs, streak-lines, ribbons)

References I

Alberto Cairo. *The truthful art: Data, charts, and maps for communication*. New Riders, 2016

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